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An Activity Report on Protecting and Monitoring Our Ocean Resource

1. Introduction

Ocean resources include living marine resources such as fish, marine mammals and sea birds, corals, kelp, plankton and algae, and non-living resources such as shoreline, oil and gas reserves, sand, salt and sea water itself. These resources account for a significant portion of the U.S. economy in goods and services; recent estimates for just the coastal areas alone are at least 28 million jobs, millions in goods and services, and an attractive tourist destination for 180 million Americans every year. The health and availability of these resources affect millions of U.S. citizens, tourists and our bordering neighbors. U.S. coastal areas are among the most developed in the nation, with over half of our population residing within less than one-fifth of the land area in the contiguous U.S. Coastal and ocean management is critically important to the environment, economy and public safety. Our ability to actively observe, protect and sustain US coastal and ocean resources is essential to ensure these societal benefits for future generations.

Many U.S. ocean resources are found in coastal regions (top of the watershed to the EEZ), but some of interest to the U.S. such as sea birds, fish and marine mammals extend well beyond U.S. borders. While improvements have been made in water quality, delisting of some overfished species, and rebounds in certain marine mammal populations, much work remains to be done. Critical living ocean resource issues include declining fish stocks, loss of marine mammals, sea turtles, bird species and populations, introduction and proliferation of nonindigenous species, loss of biodiversity, and degradation and restructuring of relevant coastal and marine habitats including water quality. There is also an increasing need to quantify and predict the effects of climate change, including sea level rise and effects of extreme weather events, on coastal and open ocean resources. Fundamental to management of ocean resources is the requirement to balance the need for increasing energy, coastal development, marine transportation and national security demands with preserving healthy and sustainable coastal and marine ecosystems and coastal communities.

To make the most effective decisions for protecting and preserving ocean resources, accurate information from an ocean observing system is required to allow for detection and prediction of the causes and consequences of changes in marine and coastal ecosystems, watersheds and non-living resources. The draft recommendations of the U.S.Commission on Ocean Policy (2004), White Water to Blue Water (see http://www.state.gov/g/oes/rls/fs/2002/15624.htm) and other reports and studies endorse an ecosystem approach and/or a watershed approach for the ocean observing system. This system should be able to assess and predict phenomena such as impacts of climate change and weather events like coastal storms, natural and man-made hazards such as oil spills and pollution, and other activities such as fishing, recreational activities, marine transportation, coastal construction and development and ocean drilling/exploration. Observations gathered from ships, aircraft, satellites, drifters, buoys and other remote and in situ sensors are needed for a wide range of physical, biological, chemical, geological and atmospheric variables within U.S. coastal regions, islands and territories, and open ocean regions. Coordination of this information obtained at various time and space scales, from periodic sampling to real time observations, and from existing, nascent and planned networks is complex and will demand dedicated resources, commitment and focus to accomplish. Just as critical will be the development and implementation of coupled physical-biological (ecological) models, development of products and services that translate available information into rapid and long term assessments, forecasts and decision tools for a wide range of users, from skilled researchers to fishing captains that rely on radio transmissions, all supported by a responsive research enterprise.

These requirements call for a sustained, integrated ocean observing system (IOOS) that is robust, rigorous, reliable, responsive and effective. An IOOS is currently being planned by the U.S. that consists of a national backbone of observations and integrated data management by appropriate federal agencies, and a federation of regional coastal ocean observing systems ("regional associations"). The regional associations include state and local governments, academic institutions, private sector and non-profit companies and serve the entire coast of the U.S., including the Great Lakes (see www.ocean.us for details on current plans). Appendix I contains a list of societal goals to be met by IOOS; these goals overlap many IWGEO themes. Appendix IX details a use case for how IOOS has already provided economic benefits to society.

2. User Requirements

User groups for ocean resource information include a wide range of users with various data and information needs, capabilities and missions, including federal agencies, state and local governments who have federal laws and mandates to fulfill, the shipping industry, port authorities, law enforcement, public health sector, insurance industry, economic development boards, coastal resource managers, regulatory authorities, non-governmental organizations, tourist industry, coastal engineers, sanitation district officials, emergency managers, research scientists, recreational users, home owners, fishing industry, and the military. Some users are also suppliers of critical ocean information. Users can be coastal managers who make near-term and long range decisions on coastal resources, ship captains navigating ports and harbors, wind surfers trying to locate the best currents, oil and gas companies drilling for oil, or researchers developing a new technique to remotely monitor salinity. Detailed lists of users can be found in a variety of recent reports listed in the references, including: the U.S Commission on Ocean Policy (2004); National Ocean Oceanographic Partnership Program/ National Ocean Research Leadership Council (1999 and 2003); Intergovernmental Oceanographic Commission (2000); NOAA *et al*. (1999); and OCEAN.US (2002). Appendix II provides a cross walk of core variables required for ocean resources/IOOS and ocean resource themes.

Ocean resource users need a wide variety of information ranging from raw data and data products to assessments, predictions, and decision tools. They need to be able to find the data or information products they need, overlay or compare with other data and products, and translate the information into actions and decisions.

High level needs to satisfy these users are:

1) improved weather forecasts, climate predictions and information products to help mitigate natural hazards
2) assessments of the state of marine ecosystems, watersheds and the resources they support
3) development and implementation of scientifically sound environmental policies that take into account natural and anthropogenic changes in marine ecosystems and the effects of these changes on people.

More specific information needs are:

1) More accurate estimates of inputs of freshwater, sediments, nutrients, organisms and contaminants from all sources into coastal waters;
2) Better understanding of how geomorphology and depth govern the response of coastal ecosystems to external forces or drivers
3) Improved marine meteorological forecasts, nowcasts, ocean and coastal circulation models
4) More timely quantification and detection of environmental trends, such as climate change and coastal population shifts, and their impacts on ecosystems
5) Better understanding of ecosystem dynamics and its effect on marine resources
6) Better assessments of the impacts of climate change and weather events on coastal ecosystems and communities

Specific local or regional issues that need to be addressed include, but are not limited to, nutrient enrichment, oxygen depletion, harmful algal blooms (HABs), chemical contamination, fish kills, habitat loss, shoreline erosion, increasing susceptibility of coastal communities to natural hazards, declines in marine resources, loss of biodiversity, invasions of non-indigenous species.

To address user needs and to implement an ecosystem/watershed-based approach to protecting and managing ocean resources, an initial list of required physical, biological, chemical, geological and atmospheric parameters has been developed for IOOS, and is found in Appendix III. Observing data are critical inputs into sophisticated models, timely and rapid forecasts and assessments of the status and trends of marine ecosystems and watersheds. Key users need observing systems from which data and information will help predict and mitigate events that affect the marine/watershed environment and related economic interests. Data sets and models are needed for immediate action (e.g. response to an impending HAB), or for long term planning (e.g. mitigation of coastal inundation caused by sea-level rise). Available in OCEAN.US (2002) are listings of existing or required information products derived from the observing data. These products vary in their level of complexity and detail, ranging from a facsimile of a weather map of the coastal region, to a combined product of in situ and remotely sensed data, to outputs of sophisticated coupled physical-ecological models. Also required for an ecosystems approach are:

1) climatologies of core variables (hindcasts);
2) improved nowcasts of their spatial distribution (fields);
3) forecasts of changes in these fields that affect the distribution and abundance of living organisms and the condition of habitats upon which they depend; and
4) sentinel/research sites.

Another crucial requirement for an “integrated” ocean observing system (IOOS) is recognizing communities of living organisms, including humans, occupy the physical environment. Also, communities are influenced by the physical environment, and influence each other by consuming the environment’s resources. ‘Living resource’ managers clearly recognize the need for information on environmental processes to characterize the range of consumable and protected species they seek to maintain at sustainable population. Similarly, the physical oceanographic and climate communities must recognize their dependence on the biological communities' physical resources and processes, and how they affect the system. Addressing both abiotic and biotic information needs will ensure an IOOS that addresses the full ecosystem spectrum.

Other critical characteristics of the integrated ocean observing system include:

1) stable, sustained near-to-real-time data sets from in-situ and remote sensors;
2) operational models providing outputs in near-real-time;
3) the capability to develop and test new models, instrumentation, and data management and analysis tools;
4) a network of robust calibration and validation systems to ensure the accuracy and stability of data inputs and model outputs;
5) supporting research to develop and evolve new sensors, techniques, assessment tools and models;
6) a process to assimilate high value research projects into the operational system.
7) skilled personnel
8) access to real-time, non-real time or archived data that is easily combined or assimilated into products, models, simulations, long term trends
9) decision tools and assessments

More details about IOOS to be provided.

3. Deployed Observing Capabilities and Commonalities:

There are many existing capabilities for monitoring ocean resources within federal agencies, state and local government, private companies, academic institutions, tribes, non-governmental organizations and others. Some have been in place for decades or years, while others are implemented only for short term projects or studies. These systems were designed to support national mandates, living marine resource conservation, local management issues, specific research projects and other clients with varying purposes and user needs. They can be considered global, national, regional or local in nature, are in various states of readiness, and have various levels of support. Surface-based capabilities include ship-acquired data, buoy or land-based networks, drifters, expendable bathythermographs (XBTs), and underwater laboratories. Airborne and satellite systems include multispectral, hyperspectral, lidar, and radar-based sensors. Specific sensor types and networks include:

1) Remote sensing instruments on aircraft, satellite and land-based platforms, such as: optical imaging sensors (multispectral and hyperspectral); thermal imaging sensors; passive and active microwave and high frequency radar; and lidar

2) Ship-based measurements, such as: net sampling; manual and pumped measurements of physical, chemical, optical and biological properties; and acoustic measurements of bathymetry and currents

3) Coastal, open ocean, or land-based in situ systems, such as: wind, wave and temperature sensors on moored buoys; shore based platforms such as tide gauges; water quality sensors; and autonomous underwater vehicles (AUVs)

4) In water measurements, such as: manual sampling of underwater species; remotely operated vehicles (ROVs); and underwater video/photography

5) Sentinel and research sites located: at the shoreline; in bays, estuaries, rivers, offshore, and the deep ocean; and on the ocean floor

6) Systematic regional fisheries and protected species surveys conducted by ships and aircraft to establish seasonal indicies of abundance and distribution, and, from these, key indicator species over time

7) Long-term sampling programs that measure contaminants in the water column, sediments and marine organisms, such as NOAA's National Status and Trends Program.

Orbital sensors are available on satellite missions, such as: NOAA's Polar Earth Orbiting Satellites and Geostationary Earth Orbiting Satellites; DOD's Defense Meteorological Satellite Program, NASA's Landsat, SeaWiFS, Terra, Aqua, TRMM, TOPEX/Poseidon and Jason-1 satellites; and various commercial ventures. Examples of global in situ systems include the Argo buoys, and the U.S. contribution of buoys, land-based platforms and expertise as part of the Global Sea Level Observing System (GLOSS). National in situ systems include: NOAA's National Data Buoy Center (NDBC) networks of weather buoys and land-based measurement stations, National Water Level Observation Network (NWLON), and NOAA's Ecosystem Observation System (NEOS); EPA's National Coastal Assessment Program and National Estuary Program; and the USGS stream gauge network. Examples of regional and local systems include the Rutgers University Coastal Ocean Observation Laboratory and the water quality monitoring networks of Southern California's sanitation districts. Many of these systems measure the same variables using the same, similar, or even different equipment and techniques. They may have different data collection frequencies, spatial scales, data quality control and processing procedures, and formats residing in databases or other media. Data may be available in real time, in a delayed mode, after days, months or years of processing and analysis, or not at all. An inventory of deployed systems is found in U.S. Ocean Commission (2004), in OCEAN.US (2002) and in other reports such as the Department of Commerce/NOAA, December 2003 draft report "NOAA's Integrated Environmental Observation and Data Management System". A listing of the systems considered as initial candidates for IOOS , along with measured parameters, is found in Appendix IV.

Of particular note is NOAA's Ecosystem Observing System (NEOS), an end-to-end coastal and oceanic ecological observing system for living marine resources (LMRs) that supports the NOAA's ecosystems management mandates. NEOS encompasses routine, operational[1] and pre-operational observations (e.g.,

[1] Operational systems are the final part of a continuum ranging from research to pilot projects to pre-operational and then operational activities. An operational system is defined as one with routine and sustained provision of data and data products in forms and at rates specified by user groups, and is run by operational groups, with researchers functioning as advisories and users. A pre-operational system is defined as one that incorporates new techniques from pilot projects into operational systems that are likely to lead to value added product(s) and is run primarily by operational groups, but with involvement of researchers (Ocean US (2003) U.S. Integrated Ocean Observing System part I).

[2] Operational systems are the final part of a continuum starting with research-pilot projects-pre-operational and then operational activities. An operational system is defined as "routine and sustained provision of data and data products in forms and at rates specified by user groups and are performed by operational groups with researchers functioning as advisories and users. A pre-

resource surveys), product development (e.g., assessments and forecasts), and research necessary to improve the technical capability of the Observation System to monitor and assess LMRs. NEOS also includes data management and production of routine technical reports (e.g., LMR stock assessments). This system will link to efforts of the EPA and USGS as outlined in subchapter 4.6. A companion to NEOS is the Ocean Biogeographical Information System (OBIS), considered to be a candidate for the main depository (portal) for the storage and disposition of biological data to be collected. See http://www.iobis.org for more details.

For the most part, deployed systems are not linked in terms of data discovery, availability or integration (ability to "overlay" datasets). Instrumentation for meteorological measurements, water temperature, salinity, and current speed and direction is available and widely deployed, but may not be available in some critical coastal or open ocean areas. Instruments used for water quality measurements are available, with others in varying degrees of development, but they are not uniformly deployed in threatened areas or baseline sites. Bio-optical instrumentation is available and used in an operational mode, with more instruments ready for transition from research to operations, but maintenance issues, such as bio-fouling, are still a significant problem and spatial coverage remains inadequate. Nearly operational nutrient sensors are being considered for various issues such as eutrophication in aquatic environments, occurance of HABs, etc. Some of the new technology incorporates automated and above water measurements required for the calibration of satellite remote sensing data, but more sites are needed, especially in coastal regimes. Automated instrumentation for the detection of HABs is not available; however, there are several promising technologies in development.

For the initial IOOS, the "national backbone", existing federal systems that provide sustained and reliable core parameters (Appendix II), will consist of deployed systems which provide one or more of the following measurements in a sustainable, routine and standardized fashion for the global ocean:

- sea surface wind, wave and current fields;
- sea level;
- surface and interior fields of temperature and salinity;
- heat flux across the air-sea interface; and
- sea ice distribution and extent.

The initial IOOS will also supply the following coastal parameters in a sustainable, routine and standardized fashion:

- surface and interior fields of chlorophyll-a and macrozooplankton abundance;
- extent and condition of benthic habitats;
- distributions of spawning stocks of harvestable fish species; and
- land-sea freshwater flows and associated transports of sediments, nutrients and contaminants.

Appendix IV provides a partial listing of the existing federal observing systems and the required parameters collected for the IOOS national backbone, but is not complete and will need to be augmented by IWGEO agencies. Among the high priority variables for the backbone are wind, air pressure, precipitation, sea level,

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operational system is defined as incorporation of new techniques from pilot projects into operational systems that are likely to lead to value added product(s) with the primary responsibility for this state from operational groups with involvement of researchers (Ref: Ocean US (2003) U.S. Integrated Ocean Observing System part I).

bathymetry, temperature and salinity throughout the water column, surface currents, surface waves, photosynthetically active radiation (PAR), turbidity, phytoplankton pigments, ocean color, dissolved inorganic nutrients, dissolved oxygen, sediment type and grain size. In addition, LMR assessments and forecasts require information on fisheries and protected species stock identification and structure, abundance and seasonal distribution, habitat requirements and prey and competition species status. These measurements are made from a variety of platforms, including ships, aircraft, satellites, and in water sensors. Some of these variables are easily accessible and can be overlaid with data from other systems, and some are not.

The appropriate composition of the IOOS backbone, e.g., the systems that will be "integrated" at appropriate time and space scales to provide required products and information to users, will need to be determined, and will be based on collated and prioritized user requirements. Instrumentation from state and local governments, private sector or academic systems that are sustained and standardized (see a comprehensive listing in U.S. Ocean Commission, 2004) are also expected to be part of IOOS. These observational systems should be designed to allow for expansion as new operational instrumentation becomes available, as well as for the deployment of research instrumentation. Considerable detail about the stage of readiness for deployed observational systems is found in OCEAN.US (2002).

Easily accessible databases of these measurements are also required, with formats that allow for integration at the user desktop, allow for intercomparisons and modeling hindcasts and forecasts, allow for assessments and simulations, and allow for development of products that illustrate current conditions, temporal variability and long term trends/future conditions. Additionally, IOOS must support machine-to-machine interoperability with semantic meaning; i.e. incorporate some collection of methodologies that promote the scripted exchange of data between computers, with all computers involved in the transaction capable of determining both the syntax and the semantics of the exchanged data without human intervention.

4. Major Gaps and Challenges:

By the very nature of the complexity, interrelationships, time scales involved and extent of the phenomena involved in protecting and monitoring ocean resources, the implementation and evolution of a sustained and integrated, locally relevant and globally deployed IOOS will be a substantial challenge. IOOS can and should look to the example of the weather system for best practices and policies, standards and protocols and, if possible, for leveraging existing assets, and to international efforts such as EuroGOOS. However, full implementation and evolution of the system will require substantial and sustained investments in all major components: data acquisition/data processing/data management (infrastructure); data and product communication; modeling of physical-ecosystem/watershed systems; research and development of new products, services and observational techniques; skilled personnel and administrative/financial systems. A concentrated effort will be required to more thoroughly understand marine ecosystems and the watershed environment, determine the optimum, best-value observing system to put in place, evolve and determine effectiveness on a regular basis, establish the key indicators of change, and determine how to implement and interpret assessments of interactions among ecosystems and the human population to make the most informed decisions about ocean resources.

Issues to overcome with respect to the observing components include: insufficient spatial distributions of observing sites; monitoring at inappropriate or inadequate time scales or patterns of variability; collection of measurements in different units and of varying quality; and delays in data collection, quality control and dissemination. Appendix V is an example of a partial gap analysis for some observational parameters. OCEAN.US (2002) also contains considerable detail about gaps for all required IOOS parameters.

Preliminary assessments of user needs have determined that enhancements to key variables in both time and space are needed for coastal and open ocean regions, prioritized according to the following criteria:

1) the need for a consistent set of backbone ("core") measurements (Appendix II), over multiple scales, local to global, hours to decades, for the open ocean, coasts, Great Lakes to a) monitor and assess near shore processes, b) obtain spatially adequate and synoptic long term time series, c) provide transects and vertical profiles of key parameters, and d) provide high resolution vertical profiles;

2) the need for time series of vertical distribution of key variables at "sentinel sites", e.g. to determine baseline conditions in a wide variety of coastal water and open ocean conditions;

3) a summary of proposed next steps for indicators (products) of ecosystem condition, by panels of experts both within the U.S. and internationally, and in reports such as the Heinz Center (2002) report on "The State of the Nation's Ecosystems".

A comprehensive detailed assessment of the data that are available is needed, based on existing OCEAN.US and draft U.S. Commission on Ocean Policy documents. This assessment should be compared with user needs from regional ocean information programs, which include representatives from the public (including Homeland Security agencies), private and academic sectors, along with the general public. As stated in the draft U.S. Commission on Ocean Policy report, user inputs are critical to defining specific information needs, operational requirements and outputs that would be most useful for various ocean resource needs. These needs will, in turn, drive observation system improvements.

To manage and provide needed information products for a wide variety of users, easily accessible databases that allow for rapid delivery of information and products are critical. These databases will allow for integration of observations into information products at the user desktop, cell phone or bridge of the ship, and intercomparisons and trends analyses of parameters and variables. The databases will also provide for coupled atmospheric/ocean/biological model outputs of hindcasts and forecasts, assessments and simulations, and development of products that illustrate current conditions, temporal variability and long term trends/future conditions. The IOOS data management and communications system (DMAC) plan is being designed for these purposes and addresses data standards, discovery, transport and archival. More information about DMAC can be found at www.ocean.us.

The role of research for developing an ecosystem approach to management approach that provides for the monitoring and stewardship of coastal and ocean resources cannot be overstated. An ecosystem approach to management that is adaptive would serve as the underlying concept for managing ocean resources, but the scientific principles for implementing this concept are not yet fully understood nor fully developed. The development and adoption of an ecosystem approach to coastal and ocean resource management will need to be incremental and collaborative, with clear definitions and technical guidelines, and build on existing capabilities. Physical and chemical oceanography, as well as the biological and ecological complexity involved in an ecosystem approach to management, must all be understood and accounted for. Dedicated basic and applied research is needed to support improvements to existing or development of new measurement systems (remote sensing and in situ), and to improve fundamental observing strategies for monitoring and managing resources. One example is the development within EPA of suspended and bedded sediments (SABS) water quality criteria. An important contribution of the research components of IOOS will be to provide an improved understanding of the state of marine ecosystems, their natural sources of variability and their sensitivity to potential changes in the global climate system. This new knowledge will lead to a more effective application of ecosystem principles for managing resources. Also critical is a good understanding of the socio-economic variables and trends related to ocean resource management. One particularly important output for this research will be improved data assimilation techniques and models that integrate physical, biological, geological and chemical data.

Evolutionary changes in in situ measurements of key variables are also expected from all sectors, public, private and academic, with corresponding changes in data communication, local data processing, and assimilating of new data into management models. For example, more accurate and comprehensive remote sensing of key variables, particularly in coastal regions, is anticipated from new sensors on new satellite, aircraft, vessel, and autonomous vehicle platforms.

Among the broad challenges are to implement and evolve a system that satisfies the most users in the most economical fashion and for operators to agree on data standards for the high priority variables and other variables that are added over time. Integration of observations with models, ecosystem characterization, simulation and decision support services for ecosystem based management practice need more emphasis, and the place-based distributed nature of problems, solutions, observations and connections to managers must be taken into account. A significant, cooperative effort will be necessary to develop a monitoring system for living marine resources, building on existing programs within the federal agencies and of other partners within the IOOS.

Transitioning new knowledge into better measurements systems and improved deployment strategies for IOOS requires effective partnerships between researchers, resource managers and those designing and implementing IOOS components.

Differentiating the effects of human activities from natural processes will require knowledge of the coherence of changes that are occurring locally on global scales and comparative analysis of such changes in the context of larger scale forcings. Therefore observations, analyses and comparative studies are needed well beyond the borders of the U.S., involving other countries in an integrated effort. Knowledge, data, infrastructure and expertise must be shared among nations for the most effective effort.

The bathymetry, chemistry, physics and biology of the Antarctic and Arctic Oceans are influenced by ice cover, and will require new techniques and special instruments. Open ocean moorings and remote sensing will not be useable for all parameters in these regions. New technology developments are required, for example, real time or near real time data from bottom moored instruments will require special data download capabilities.

Some key observational gaps are:–

Remote sensing:

1) Better procedures for calibrating and representing data in coastal waters
2) Precise sea surface height and surface vector wind measurements
3) Finer scale resolution sensors for SST, salinity, winds, ocean color (specific information can be obtained from NOAA Mission Observations Requirements List (MORL) for Environmental Satellites documents)
4) Continuity in ocean color, winds and sea surface height measurements
5) Better systems to determine quantity and quality of coastal habitats (intertidal, seagrasses, kelp beds, water column, sediments)
6) Need to acquire ocean color imagery (multi- and hyperspectral) of coastal areas at sufficient frequency and optical resolution to identify and analyze changes in the spatial distribution and extent of coastal and nearshore habitats

Ship-based:

1) More ship-based measurements of temperature and salinity profiles (need to equip more ships of opportunity)
2) Better determination of global fluxes of heat, fresh water and carbon (need to repeat a World Ocean Circulation Experiment [WOCE] – type experiment)
3) Comprehensive and standardized fisheries and protected species surveys to measure relative abundance from fishery-independent data to improve the quality of LMR stock assessments and the understanding of population dynamics, e.g. more days at sea
4) Better instrumentation for physical, chemical and biological information
5) Multi-beam sonar measurements to collect detailed bathymetry and habitat information, particularly in nearshore and shelf environments

In situ:

1) Long-term, continuous measurements of river flow volume at more sites
2) More sites for water level measurements
3) More frequent sampling of key properties, such as sediment load, nutrient concentration and selected chemical contaminants, at more sites
4) Better systems to determine quantity and quality of coastal habitats (intertidal, seagrasses, kelp beds, water column, sediments)
5) Expanded coastal network of moored instruments at more locations that measure meteorological variables (including atmospheric deposition) and oceanographic properties (physical, chemical, biological)
6) Additional deep ocean observatories and sentinel sites
7) New remote sensing/AUV technologies/techniques to obtain fishery-dependent and fishery-independent data
8) Innovative and cost effective techniques to eliminate the need for manual sampling, photography, etc.

9) Standardization of methodologies for biological community sampling
10) Improve methods for validation of benthic habitat map products

Other challenges include needs for the following:
(THESE WILL BE BETTER ORGANIZED IN THE NEXT DRAFT)
1) Assimilation of remotely sensed data into models
2) Continued improvement of coupled biological-physical models
3) Tools to transform measurements into products such as predictions of environmental change, and analyze the efficacy of management actions
4) Integration of in situ measurements with remotely-sensed observations
5) Identification and establishment of additional sentinel and research sites
6) A system that is adaptable to technological, institutional, economical change, and changing priorities.
7) Effective partnerships between government (including the military), industry, and academic institututions, which provide for continuous integration, sustainability and innovation of the observing system, and overcome parochial attitudes and approaches
8) A method for prioritizing observing system enhancements, based on cost benefit analysis and scientific value
9) A system to measure the observing system effectiveness and value
10) A system to transition research efforts into operations.
11) Closing gaps in knowledge of ecosystem effects upon LMR's, including the effects of environmental variability and climate change, functional habitat alteration, and long-term environmental degradation
12) Closing gaps in knowledge of multispecies interactions so they can be incorporated, along with ecosystem considerations, into stock assessments and management advice
13) Systematic research, monitoring, assessment, and technology development required to truly achieve meaningful sediment management. The impacts on natural sediment processes of dredging, infrastructure projects, farming, urban development, any many other necessary and beneficial human activities are not well understood.
14) A systematic, sustained, monitoring system for water quality on national or global geographic scales necessary to meet the needs for assessment of impacts of decreasing water quality on living marine resources, habitats, and human health and the economy.
15) collaborative projects among scientists and commercial and recreational fisherman to increase understanding of mutual needs and expertise.
16) Research on the impacts of all types of vessel pollution.
17) Expand research and development efforts to encourage multidisciplinary studies of the evolution, ecology, chemistry, and molecular biology of marine species, discover potential marine bioproducts, and develop practical compounds
18) Support for U.S. scientists conducting research programs around the world.
19) Identification of the critical research and data needs related to coral reef ecosystems, through the U.S. Coral Reef Task Force
20) Additional research into ocean acoustics and the potential impacts of noise on marine mammals
21) Expansion of marine aquaculture research, development, training, extension, and technology transfer programs

22) A determination of whether methane hydrates can contribute significantly to meeting the nation's long-term energy needs
23) Significantly reduce nonpoint source pollution in all impaired coastal watersheds, and set specific, measurable objectives focused on meeting human health and ecosystem based water quality standards
24) A national program for social science and economic research to examine the human dimensions and economic values of the nation's oceans and coasts and encourage ocean research agencies to include socioeconomic research as part of their efforts
25) Coordination of federal agencies that manage, assess, map, and chart resources, with the goal of creating standardized, easily accessible national maps that incorporate living and non-living marine resource data along with bathymetry, topography, and other natural features. Investigate expansion of existing and creation of new data clearinghouses for marine spatial data to more effectively share multi-agency data.
26) Inclusion of pipelines, off shore platforms, vessels, and related research and monitoring programs in IOOS.,
27) Flexible data policy for classified data and other datasets involving commercial interests (e.g., fishing information, precise geophysical information of interest to the oil and gas industry,etc.)

5. Partnerships (National & International):

(NEED MORE INPUT FOR THIS SECTION)
Federal agencies are involved with a number of national and international partnerships involving ocean resource data And Appendix VI contains a table showing a partial list of existing partnerships. In addition, there has been considerable national and international activity and cooperation over the past 10 years toward the development of an IOOS. There has been an interagency effort to create a national and international network of observations, data management and analyses that systematically acquire and disseminate data and information on past, present and future states of the oceans, particularly with the Exclusive Economic Zone (EEZ). IOOS is the U.S. component of a larger Global Ocean Observing system (GOOS) that is being developed under the auspices of IOC/UNESCO.

IOOS is being developed as a national partnership among federal and state agencies and regional associations that represent both users and operators of the system. The National Ocean Research Leadership Council (NORLC) develops policies and procedures for IOOS design and implementation, and receives advice from the Ocean Research Advisory Panel. NORLC approved the establishment of an office (OCEAN.US), having the charter to oversee the development of a national capability for integrating and sustaining ocean observations and predictions. NORLC's Executive Committee (EXCOM) oversees all the activities of the OCEAN.US office, and is composed of representatives from 10 federal agencies (see http://www.nopp.org). Participating government agencies and regional associations implement those elements of the IOOS that are consistent with their missions, goals, and priorities. International coordination and cooperation is maintained through the U.S. Global Ocean Observing System steering committee, which is represented in the GOOS effort. GOOS is coordinated through UNESCO/IOC.

Joint partnerships within relevant agencies are required for:

1) the development of a strategy for assessment, monitoring, research, and technology development to enhance sediment management;

2) a national water quality monitoring network that coordinates existing and planned monitoring efforts, including monitoring of atmospheric deposition, and that provides timely and useful information products that are easily accessible to the public and linked to output from the IOOS

3) a plan for transferring new technologies to an operational mode in the IOOS;

4) a joint ocean and coastal information management and communications program to generate information products relevant to national, regional, state, and local needs on an operational basis;

5) periodic review and declassification of appropriate oceanographic data for access by the ocean community.

6) the use of industry resources with the offshore oil and gas industry

6. U.S. capacity building needs:

(NEED MORE INPUT FOR THIS SECTION)

Current capabilities and capacities are insufficient to satisfy national and international requirements. At a minimum, capacity building must involve:

1) developing and maintaining the basic technical expertise and infrastructure required to participate in IOOS
2) educating the public and governments concerning the benefits of investing in IOOS.

To achieve 1), the IOOS philosophy of combining the capabilities of public, private and academic sectors could be considered to address key priority areas. Design principles will be guided by a coalition of data providers and users and procedures will be established for user groups to routinely evaluate the performance of IOOS and assess the value of the information produced. One important step forward will be to inventory current capabilities and to keep the inventory and future plans current and available to all stakeholders and suppliers. Other key areas for enhancements are data management and communication, combining remotely sensed data with in situ data, and providing enhanced sensor packages and remotely sensed technologies and/or modeling to increase the observational network capacity. For 2), increased education and training of coastal managers and the public on how to use available information and products in both a stand-alone and integrated manner are needed.

Other specific needs include:

1) Additional habitat conservation and restoration assessments, monitoring, research, and education;

2) Additional sustainable development and conservation of renewable ocean and coastal resources through grants to all coastal states;

3) Greatly expanded national ocean exploration program

4) Sustainable support for all aspects of IOOS, from research (applied and basic), to pre-operational and operational systems, pilot projects, and data management and communication systems.

Appendix VII displays a required variable and some associated gaps and suggested capacity building activities related to ocean resources.

7. Future EO systems

(NEED MORE INPUT FOR THIS SECTION)

Evolutionary changes in in situ measurements of key variables are expected, with corresponding changes in data communication and local initial data processing (QC/QA checks for example). More accurate and comprehensive remote sensing of key variables in coastal regions is expected in the next generation of satellites, aircraft, ships and AUVs. Additional details will be identified in the process of developing gap analyses and future requirements. An example of current and future EO systems for ocean resources is found in Appendix VIII, and future needs are Documented in OCEAN.US, 2002.

8. Summary

A basic objective of IOOS for the coming decade is to generate the optimal value (i.e. maximize net benefits) to society from our nation's oceans and coasts in a sustainable and environmentally healthy manner, including uses for commerce, transportation, food supply, and energy. Priorities include ensuring food security through sustainable management of fisheries and aquaculture, improving water quality and management of management of sediments and shorelines, promoting safe and free transit and navigation, and minimizing and/or mitigating the occurrence of coastal and ocean-related hazards. Taken together, these priorities will promote healthy coastal and ocean ecosystems, including that of human populations. They also support the other IWGEO theme areas.

Highest priority actions to protect and monitor ocean resources:

The ocean "triad" –

1. Maintain infrastructure to operate and enhance the IOOS backbone elements found in 2.
2 Enhance blue water time series (buoy, CMAN) stations with biological and chemical sensors (bio-optics, nutrients, dissolved oxygen, pCO2, etc..), add sea level gauges and river water quality and level instrumentation at more sites, and more frequently sample sediment load, nutrient concentration and selected chemical contaminants (USGS, NOAA, Navy, EPA and USACE systems)
3 Implement data standards and protocols for metadata management and data discovery, data transport, uniform on-line browse and archive for the core/backbone ocean parameters collected from the above networks.

Priorities for general and other specific investments for IOOS have been documented in NOAA *et al* (1999), NOPP (1999), OCEAN.US documents (see www.ocean.us), the U.S. Commission on Ocean Policy (2004), and are highlighted below. Additional details about timelines for implementation, and preliminary estimates of amount and cost of enhancements are found in OCEAN.US, 2002. All actions should be more thoroughly vetted within the IOOS community and among the IWGEO agencies, and agreements must be reached on the most appropriate locations to monitor local, regional and national conditions, using an agreed upon and cost effective approach.

General:

1) Establish and evolve a core set of variables to be collected by all components of IOOS, agreed upon by IOOS federal agencies and regional ocean information programs (including users). The core variables should include appropriate biological, chemical, geological, and physical variables.

2) Continuously assess the current and future capabilities of the observing systems required to monitor ocean resources similar to that found in Appendix IV and in OCEAN.US (2002);

2) Establish a network of sentinel (reference) stations to provide baseline data to assess the significance of local variability and develop early warning indicators

3) Establish standards and protocols for measurements, data exchange and management to allow for rapid access to diverse data from disparate sources;

4) Integrate global observations with coastal/regional observations to detect and predict the effects of global scale weather and climate patterns on ecosystems;

5) Enable comparative ecosystem analysis, required to develop ecological models of ecological change;

6) Minimize redundancy, and optimize data and information exchange; and

7) Facilitate capacity building within regions (which include public, private and academic sectors)

Specific conclusions:

- With key user input, identify information products that address key ocean resource issues.
- Implement data standards and protocols for metadata management and data discovery, data transport, uniform on-line browse and archive for all core/backbone ocean parameters
- Establish research and modeling priorities to address key ocean resource issues
- Establish a national surface current mapping system in the coastal areas and out to 200 km
- Transition remote sensing capabilities of ocean topography, ocean vector winds, ocean color, SST and sea ice from research to operations, sustain this capability and make more accessible.
- Continue to implement Argo, global ocean time series observatories, and the Global Ocean Data Assimilation Experiment

- Develop in situ and/or remotely sensed systems to monitor and predict changes in selected species of living resources and quality and quantity of coastal habitats (intertidal, seagrasses, kelp beds, water column, sediments)
- Expand and enhance moored instruments in inland seas (estuaries, bays, sounds Great Lakes) and in the EEZ for synoptic measurements of meteorological and oceanographic properties
- Enhance the integration of water levels, currents and waves in support of marine transportation
- Develop additional nowcasts/forecasts in all major ports and coastal waters
- Increase the frequency of high resolution bathymetric surveys of the continental shelf to support marine transportation, recreational and commercial fishing and the oil and gas industry
- Increase the frequency of combined topographic shoreline surveys and nearshore bathymetric surveys
- Establish systematic LMR surveys and assessments to develop information on LMR status trends over time
- Develop statistical modeling capabilities that integrate biological (e.g., primary production, fishery, protected resource) information and environmental information (e.g., physical, chemical, geological) to understand ecosystem forcing mechanisms that affect LMR dynamics and status, to develop forecasts and to evaluate coastal and ocean resource management alternatives and performance.

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Appendix I: The seven societal goals and related sub goals of the IOOS

SOCIETAL GOALS	SUBGOALS
Improve weather forecasts & predictions of climate change	• (1) Obtain improved estimates of surface fields & surface fluxes; (2) improve predictions on seasonal & longer time scales; (3) Detect & assess the impact of climate change on the coastal zone; (4) Establish & maintain infrastructure & techniques to ensure efficient data acquisition & effective use of information.
Improve safety & efficiency of marine operations	• (1) Maintain navigable waterways; (2) Improve search, rescue, & emergency response capabilities; (3) Ensure safe and efficient marine operations.
Provide more timely predictions of natural hazards & their impacts	• (1) Improve data acquisition capabilities on time-space scales required to assess the physical & ecological contributions to hazard-risk; (2) Improve predictions; (3) Provide timely dissemination & convenient online access to real-time hazards, observations, & warnings; (4) Complete metadata & retrospective information on all aspects of disaster reduction; (5) Improve observational capabilities by making them functional over wider areas, for longer periods, & greater reliability.
Improve national security	• (1) Improve the effectiveness of maritime homeland security & war-fighting effectiveness abroad; (2) Improve safety & efficiency of operations at sea; (3) Establish the capability to detect & predict the dispersion of airborne & water-borne contaminants in ports, harbors, & the littoral zone at home & abroad; (4) Support environmental stewardship; (5) Improved at-sea system performance through more accurate characterization & prediction of the marine boundary layer.
Reduce public health risks	• (1) Establish nationally standardized measures of the risk of illness or injury from exposure to pathogens, toxins, hazards, & dangerous marine animals (water contact); (2) Establish nationally standardized measures of the risk of illness from consuming seafood.
Sustain, protect & restore healthy marine & estuarine ecosystems	• (1) Determine regional ecological climatologies for sea surface temperature,

Sustain, protect & restore marine resources	salinity, dissolved nutrients, chlorophyll-a, & harmful algal species; (2) Provide more timely detection & improved predictions of changes in the spatial distribution & condition of biological structured habitats (coral reefs, sea grasses, mangroves, & tidal marshes), in species diversity, of indicators of coastal eutrophication, of harmful algae (presence, growth, movement & toxicity), of non-native species (presence & probability of invasion), of diseases in & mass mortalities of marine animals (fish, mammals, birds), of the effects of habitat modification on species diversity; (3) Monitor anthropogenic contaminants & their effects on organisms & ecosystems. • (1) Provide improved & more timely prediction of annual fluctuations in spawning stock size, distribution, recruitment, & sustainable yields for exploitable fish stocks; (2) More timely detection of changes in the spatial extent & condition of essential fish habitat; (3) Improved predictions of the effects of fishing on habitats & biodiversity; (4) Establish & monitor the effectiveness of Marine Protected Areas.

APPENDIX II. Cross-walk of Core Variables Required for Ocean Resource and IOOS Themes

IOOS/Ocean resources CORE VARIABLES	Weather & Climate	Marine Operations	National security	Hazards	Public Health	Healthy ecosystems
***Salinity**	X		X		X	X
***Temperature**	X	X	X	X	X	X
***Bathymetry**	X	X	X	X		X
***Sea Level**	X	X	X	X		X
***Surface waves**	X	X	X	X		X
***Surface currents**	X	X	X	X		X
Ice distribution	X	X	X	X		X
Contaminants				X	X	X
***Dissolved Nutrients**				X	X	X
Fish species					X	X
Fish abundance					X	X
Marine mammals, sea turtles and sea birds					X	X
Zooplankton species					X	X
***Optical properties**			X	X	X	X
Heat flux	X		X			X
***Ocean color**			X	X	X	X
***Bottom character**				X	X	X
***Pathogens**				X	X	X
***Dissolved O_2**			X		X	X
Phytoplankton						

species			X			X
Zooplankton abundance						X

Appendix III: Required Parameters for Ocean Resources

Physical
Water Temperature
Salinity
Vector Currents
Directional Wave Spectra
Sea Level/Tides
Ocean Sea Surface Height
Sound
Ice Concentration
Ice Thickness
Surface Heat Flux
Sediments
Suspended Sediments
Bathymetry/Topography
Bottom Characteristics
Habitat Characteristics
Seafloor Seismicity
Groundwater Discharge
River Discharge
Optical Properties

Meteorological
Wind and Gust Vector
Air Temperature
Barometric Pressure
Precipitation
Humidity
Atmospheric Visibility
Cloud Cover
Aerosol Type
Surface Spectral Radiance

Terrestrial Human Health & Use
Pathogens: Seafood
Fish Catch and Effort
Precipitation (dry and wet)
Seafood Consumption
Beach Usage

Ambient Noise
Seafood Contaminants
Wetlands: Spatial Extent

Chemical Biological
Salinity
Contaminants in water and sediments
Dissolved Nutrients
Dissolved Oxygen
Ocean Color
Pathogens: Water
Carbon: Total Organic
pCO_2
Carbon: Total Inorganic
Total Nitrogen: Water column
Chlorophyll-a

Biological
Water Fish Species, number harvested and other ecologically important species, biomass, age structure
Pelagic and benthic invertebrates
Sea turtles, marine mammals, sea birds
Reproductive outputs (eggs, larvae)
Recruitment
Water Temperature
Dissolved Nutrients
Fish Abundance/Biomass
Bathymetry
Dissolved Oxygen
Zooplankton Species
Zooplankton Abundance
Sea Level
Carbon: Total Organic
Optical Properties
Directional Wave Spectra
Sediments
Ocean Color
Vector Currents
Suspended Sediments
Pathogens: Water
Ice Concentration
pCO_2

Phytoplankton Species
Phytoplankton Abundance
Phytoplankton Productivity
Surface Heat Flux
Carbon: Total Inorganic
Zooplankton Abundance
Bottom Characteristics
Total Nitrogen: Water
Benthic Abundance
Seafloor Seismicity
Benthic Species
Ice Thickness
Mammals: Abundance
Sea-surface Height
Mammals: Mortality Events
Catch and Effort by Gear-type
Bacterial Biomass
Chlorophyll-a
Non-native Species
Phytoplankton Abundance
Phytoplankton Productivity
Wetlands: Spatial Extent
Bioacoustics
Sound

Meteorological Terrestrial Human Health & Use
Wind Vector
River Discharge
Seafood Contaminants
Air Temperature
Groundwater Discharge
Pathogens: Seafood
Atmospheric Pressure
Fish Catch and Effort
Precipitation (dry and wet)
Seafood Consumption
Humidity Beach Usage
Aerosol Type
Ambient Noise
Atmospheric Visibility
Cloud Cover

APPENDIX IV. Existing Federal Observing Systems and Parameters collected

ASSETS/Programs	OBS./	Temperature	Salinity	Waves	Currents, SSTopo	Winds	Sea Level
g Op Envir Sat (POES)	NOAA	XX					
bserving Ships (VOS)	NOAA	XX	XX				
portunity	NOAA	XX	XX				
hips	NOAA	XX	XX			XX	
ys (Tropical Array)	NOAA	XX			XX		
y Array	NOAA	XX	XX			XX	
& Sea Ice	NOAA	XX	XX			XX	
Gauge Network	NOAA					XX	XX
ter Level Observation Network	NOAA						XX
uoy Program	NAVY	XX	XX			XX	
ey Ships	NAVY	XX	XX	XX	XX	XX	
ow-on	NAVY			XX			XX
	NAVY			XX			
ry Operational Envir. Sat. (GOES)	NOAA	XX					
	NASA						
	NASA						

ASSETS/Programs	OBS./	Temperature	Salinity	Waves	Currents	Sea Surface Winds	Stream Flow	Sea Level Topo
	NOAA	XX				XX		
	NOAA	XX				XX		XX
	NOAA	XX		XX	XX	XX		
	NOAA	XX						

	NOAA	XX	XX					
A Ecosystem Observing System)	NOAA	XX	XX					
rrent Observation Program	NOAA				XX			
essment	NOAA							
eys	NOAA							
Monitoring	NOAA							
pping	NOAA							
ge Mapping	NOAA							
itat Mapping, including coral reefs	NOAA							
ange Assessment Mapping	NOAA							
server	NOAA							
	NOAA	XX	XX	XX	XX	XX	XX	
uoy Program	NAVY	XX	XX	XX		XX		
	NAVY							XX
d Data Collection Program	USACE			XX				
eys	USACE							
ging	USGS						XX	
arine Mapping	USGS							
astal Assessment Program	EPA							
uary Program	EPA							
	NOAA	XX						
al Bloom (HAB) monitoring	NOAA							
on Assessment program	NOAA							
natology program	NOAA							
tus and Trends (incl. Mussel Watch)	NOAA							
em-wide Monitoring Program (SWMP)	NOAA	XX	XX			XX		
uary Integrated Monitoring Network	NOAA	XX	XX	XX	XX	XX	XX	XX

ASSETS/Programs	OBS/	Nutrients	Chlorophyll	Habitat & Bathy	Plankton Abundance	Fish Species Dist	Population Statistics	Fish Catch
	NOAA							
	NOAA							
	NOAA							
	NOAA							
	NOAA							
rrent Observation	NOAA		XX		XX	XX	XX	
essment	NOAA	XX		XX				
eys	NOAA			XX				
Monitoring	NOAA			XX				
pping	NOAA			XX				
ge Mapping	NOAA			XX				
itat Mapping, incl. coral reefs	NOAA			XX				
ange Assessment Mapping	NOAA			XX				
server	NOAA					XX	XX	XX
l Fisheries	NOAA							XX
Statistics	NOAA							XX
uoy Program	NAVY							
	NAVY							
d Data Collection Program	USACE							
eys	USACE							
ging	USGS							
arine Mapping	USGS							
	NOAA							
al Bloom (HAB) monitoring	NOAA		XX					

on Assessment program	NOAA		**XX**					
natology program	NOAA		**XX**					
tus and Trends (incl. Mussel Watch)	NOAA	**XX**						
em-wide Monitoring Program (SWMP)	NOAA	**XX**	**XX**					
uary Integrated Monitoring Network	NOAA	**XX**	**XX**	**XX**	**XX**	**XX**	**XX**	**XX**

Appendix V. – Example Gap Analysis

Variable	Data Sources	Gaps
SST	Voluntary Observing Ship (VOS), Drifters, Orbital Sensors	Low quality data sets (VOS); Clouds/aerosols are a problem with satellite data and the data needs *in situ* help
SSS	VOS, Drifters, Buoys	Low quality data; need more *in situ* data; need orbital capability
Subsurface SST, SSS	VOS, XBTs, Tropical Atmosphere-Ocean buoy array (TAO)	Limited Salinity data for Global Ocean
Surface Currents; Tide Data	NDBC network, Coastal-Marine Automated Network (C-MAN) shore stations, VOS, TAO, PORTS, Orbital Sensors	Poor data quality in currents; poor spatial coverage; Continuity in Sea wind fields and ocean surface topography not vouchsafed
Sediment Size and Chemistry; Benthos Characteristics	Ship monitor data, *in situ* estuarine sites, Mussel Watch site network, Coastal Intensive Sites Network (CISNet) pilot studies, Satellite image data	More sites needed in crucial areas – more geographic coverage; Chlorophyll and sediment estimates from satellite sensor data in coastal waters need refinement; need better algorithms to extract bottom type in clearer coastal water areas
Global Sea Level	GLOSS, NOAA NWLON	Network needs updating; more complete geographic coverage needed
Event Induced Sea Level Shifts (e.g. Hurricanes, Tsunamis)	Satellite imagery, Hurricane Hunter flights; Pacific Rim array of tide gauges	Good for detecting hurricanes or tsunamis but forecasting needs refinement; for tsunamis need more detectors in source areas
CO_2 Flux	VOS; research cruises	Relative dearth of global data
Sea Ice	Drifters, Satellite, Airborne Lidar	Cloudiness in polar regions a problem for passive sensors; adequate active sensors needed

Appendix VI. National and International Partnerships

Partnership	Participating Agencies
Climate Change Science Program (CCSP)	• National Oceanic and Atmospheric Administration (NOAA) • National Science Foundation (NSF) • National Aeronautics and Space Administration (NASA) • Department of Energy (DOE) • Department of the Interior (DOI) • US Department of Agriculture (USDA) • National Institutes of Health (NIH)
Coastal Ocean Observations Panel (COOP)	• NOAA, NSF, NASA, DOE, EPA • U.S. Navy (USN) • U.S. Coast Guard (USCG) • U.S. Geological Survey (USGS) • Defense Advanced Research Projects Agency (DARPA) • Minerals Management Service (MMS) • Office of Science and Technology Policy (OSTP) • Office of Management and Budget (OMB) • Department of State (DOS) • U.S. Army Corps of Engineers (USACE)
Integrated and Sustained Ocean Observing System (IOOS)	USN, NOAA, NSF, NASA, DOE, EPA, USCG, USGS, DARPA, MMS, OSTP, OMB, DOS, USACE
Global Ocean Observing System (GOOS)	USN, NOAA, NSF, NASA, DOE, EPA, USCG, USGS, DARPA, MMS, OSTP, OMB, DOS, USACE
Global Water and Energy Cycle (GWEC)	NOAA, NSF, NASA
Global Ocean Data Assimilation Experiment (GODAE)	NOAA, NSF, DOE, NASA, USN
Climate Variability and Predictability (CLIVAR)	NOAA, DOE, NSF, NASA
Joint Global Ocean Flux Study (JGOFS)	NOAA, DOE, NSF, NASA, USN
World Ocean Circulation Experiment (WOCE)	NOAA, NASA
World Meteorological Organization (WMO)	NOAA, NASA
World Climate Research Program (WCRP)	USN, NOAA, NSF, NASA, DOE, EPA, USCG, USGS, OSTP
US Global Change Research (USGCR)	• DOE, NIH, DOS, DOI, EPA, NASA, NSF, USDA • Dept. of Defense (DOD) • Agency for International Development, • Smithsonian

APPENDIX VII : Example Table for Capacity Building

Variable	Gaps	Capacity Building
SST	Low quality datasets (VOS); Clouds/aerosols are a problem with satellite data and the data needs *in situ* help	Need more SSS drifters deployed; further development of networked buoy systems; possible use of Brillouin Lidar
SSS	Low quality data; need more *in situ* data; need orbital capability	Deploy more SSS sensors – both *in situ* and orbital (e.g. SMOS, Aquarius)
Subsurface SST, SSS	Limited Salinity data for Global Ocean	Develop profiling buoy networks and drifters; possible use of Brillouin Lidar
Surface Currents; Tide Data	Poor data quality; poor spatial coverage; Increased coastal coverage needed; Continuity in Sea wind fields and ocean surface topography not vouchsafed; need high resolution tide gauges with GPS receivers on them	Increased coastal coverage needed; need high resolution tide gauges with GPS receivers on them; orbital SAR data
Sediment Size and Chemistry; Benthos Characteristics	More sites needed in crucial areas – more geographic coverage; Chlorophyll and sediment estimates from satellite sensor data in coastal waters need refinement; need better algorithms to extract bottom type in clearer coastal water areas	Data synergy using hydrographic lidars and hyperspectral sensors; multi-wavelength lidars; improved hyperspectral algorithms
Global Sea Level	Network needs updating; more complete geographic coverage needed	Increased coastal coverage is needed; data needs to integrated into high resolution global coastal network
Event Induced Sea Level Shifts (e.g. Hurricanes, Tsunamis)	Good for detecting hurricanes or tsunamis but forecasting needs refinement; for tsunamis need more detectors in source areas	Need high density satellite and airborne remotely sensed winds; UAV use for outer wind structure; wind algorithm development
CO_2 Flux	Increased coverage is needed	Increased coverage is needed to resolve poor spatial resolution
Sea Ice	Cloudiness in polar regions a problem for passive sensors; active sensor lack needed spatial resolution	Orbital/Suborbital active sensors needed (with improved spatial resolution)

APPENDIX VIII. Example Table Future Theme Earth Observing System

Parameter/ Question	Implementation Details	In Situ Measurements	Technical Readiness	Operational Potential thru 2010	Partnership Potential
Global Precipitation (V1)	Requires 6-8 satellite constellation for time resolution	Rain gauges, weather radar (NOAA, WWW)	Demonstrated by TRMM and passive µwave imagers	TBD; only passive µwave currently planned	Excellent – several needed
Ocean Surface Topography (V2)	Prefer orbits that avoid tidal aliasing	Tide gauges (Global Geodedic Network)	Demonstrated. Development needed for denser coverage	Under study by NPOESS	Continuation of current partnerships likely
Ocean Surface Winds (V2)	Active / passive µwave technique required	ships, buoys (NOAA, WWW)	Demonstrated by NSCAT and Seawinds	NPOESS requirement may be fulfilled	Seawinds and follow-on cooperation with Japan
Sea Surface Temperature (V2)	Both IR and microwave needed for all-weather observation	ships, buoys (NOAA, WWW)	Excellent	NPOESS requirement	EUMETSAT coordination
Sea Ice Extent (V2)	Microwave sensors needed for all-weather measurements	Ships, airborne reconnaissance (Navy, USCG, NOAA)	Excellent	NPOESS requirement	NASDA cooperation
Marine Primary Productivity (V3)	Very precise inter-satellite calibration is essential	NASA-SIMBIOS time series studies	Demonstrated	Partially provided by NPOESS	Cooperation with Japan, Europe possible
Ice Surface Topography (V5)	Excellent vertical resolution and accuracy needed for mass balance studies	GPS (NASA, NSF)	ICEsat lidar altimetry demonstration	Not currently an operational requirement	Coordination with European radar altimetry satellite
Gravity Field (V6)	Requires high precision	Geodetic networks	GRACE demo. pending	DOD interest in precise geoid	Possible
Total Solar Irradiance (F1)	High absolute accuracy, overlap of successive records required	global surface networks (BSRN, WRDC, SURFRAD)	Excellent	NPOESS requirement	Possible
Solar UV Irradiance (F1)	Spectral resolution & good radiometric accuracy req'd	USGCRP UV network, NDSC (multiagency)	Excellent	NPOESS measurement planned	Strong history of cooperation
Earth radiation Budget (R1)	Broadband radiometry	none	Excellent	Planned on NPOESS	Possible
Snow Cover & Accumulation (R1)	Need to assess snow depth or water equivalent quantitatively	Snow transects (NOAA/NWS)	Awaiting demonstration	NPOESS requirement for snow cover	Possible
Marine Productivity in Coastal regions (R2)	High spatial and temporal resolutions needed	NASA-SIMBIOS; Coastal bio-optics (NOAA, EPA)	Excellent	Possible NPOESS derived product	Active currently

Carbon Sources and Sinks (R2)	CO_2, CH_4 column mapping is most promising approach;	Flask network (NOAA), Ameriflux/Flux Net (DOE, USDA, NASA)	Experimental technique, needs further develop.	Not currently an operational requirement	Possible
Sea Surface Salinity (R3)	Very high radiometric precision needed for passive µwave observation	Ships and moored/drifting buoys (NOAA/NSF)	Approaching readiness (done from aircraft)	Unfulfilled NPOESS requirement; Aquarius Sensor	Likely with European Space Agency
Sea Ice Thickness (R3)	Significance of ice freeboard observations remains to be established	Moored buoys (ONR)	High spatial resolution radar; develop. needed	Desirable	Possible with domestic / international partners
Polar ice sheet velocity (R5)	Synthetic aperture radar interferometry; high latitude coverage (polar orbit) needed	GPS (NASA, NSF)	Demonstrated	Desireable	Possible
Ocean Surface Winds (C1)	Active µwave technique	ships, buoys (NOAA, WWW)	Demonstrated by NSCAT and SeaWinds	Yes	Seawinds cooperation with Japan; EUMETSAT
	Passive µwave radiometry / polarimetry to be demonstrated	N/A	Windsat/Coriolis demonstration funded by DOD, USN, NPOESS	NPOESS requirement may be fulfilled	Possible
Primary Productivity (C2)	Global 1 km or better resolution needed	NASA-SIMBIOS, GOOS, GTOS, crop, forest inventories (USDA, FAO), LTER (NSF)	Excellent	NPOESS requirement	EUMETSAT coordination
Coastal Region Properties and Productivity (C3)	Multispectral radiometry at high spatial and temporal resolution from GEO	Coastal observations (NOAA, EPA)	Excellent	Not currently	Possible
Deep Ocean Circulation (P3)	Requires *in situ* oceanographic observations	Ships and ARGO floats (NOAA, NSF)	WOCE, GODAE research projects provide initial data base	Operational Global Ocean Observing System is being envisaged	Multi-agency, international cooperation is anticipated

APPENDIX IX

USE CASE: Surface Current Measurements for Oil Spill Mitigation
Scenario:
Emergency responders can deal with dangerous oil spills more effectively and at lower cost if they have information about surface currents at a spill are in real time. Their forecasts of oil trajectories can be even more accurate if predictions of surface currents are available.

To that end, the Texas General Land Office (TGLO) funds a network of surface current-measuring buoys known as the Texas Automated Buoys System (TABS). Since 1994, the network has reported the buoys' observations offshore Texas and Louisiana in the Gulf of Mexico in real time to validate a computer model that estimates and forecasts surface currents over the Louisiana-Texas shelf.

The importance of real time current data in spill response was demonstrated in March 1996 when a barge spilled 5,000 barrels if fuel oil at the entrance of Galveston Bay. Working together, the National Oceanic and Atmospheric Administration (NOAA) HAZMAT modeling team and the TGLO's trajectory modeling team used TABS data and computer simulations to forecast the oil's movement to an unprecedented level of accuracy. The modelers knew the current's direction within minutes of the spill, and it was continuously tracked for the next 24 days.

During the first half of the spill, currents were to the northeast, indicating a strong threat to Sabine Pass on the Texas-Louisiana border. Based on the TABS data, the trajectory modelers predicted a switch in direction toward the southwest. A few hours later, they saw their prediction become a reality, recorded in real time by a TABS buoy.

Managers discontinued the alert to the Sabine Pass and refocused efforts on the area down the coast projected for impact. They were able to make this decision a full day earlier than would have been possible before the TABS network existed.

Without the TABS data, preparations for protection of Sabine Pass would have continued, resulting in wasted time, effort, and resources ($225,000) in an area that was no longer threatened.

Since then, TABS has been called on to provide information for command decisions in more than two dozen spills along the Texas coast.

The data from the TGLO-funded system are integrated into the Integrated Ocean Observing System(IOOS) by NOAA's National Data Buoy Center.

Architectural Issues:

This scenario illustrates how Earth Observation data, this time from the IOOS component, are combined with models to provide data critical to the successful protection